γ-Jet in sPHENIX

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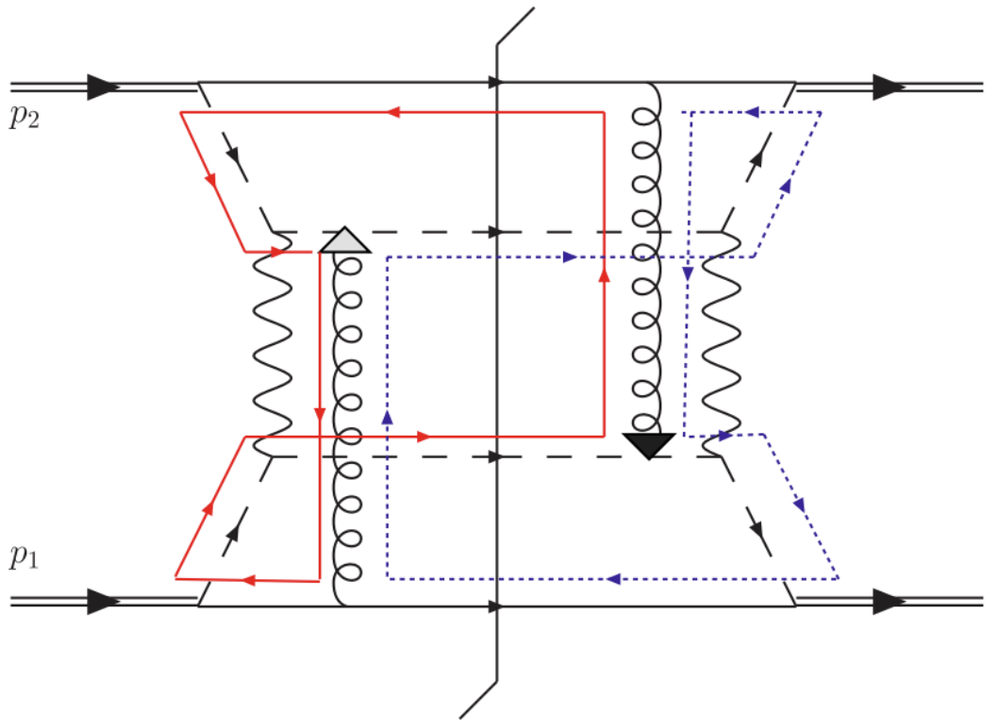
Physics Motivation

- PRD 81,094006 (2010) predicted factorization breaking in p+p—>h_1+h_2+X

- Nonperturbative PDFs and FFs quantum mechanically correlated across hadrons

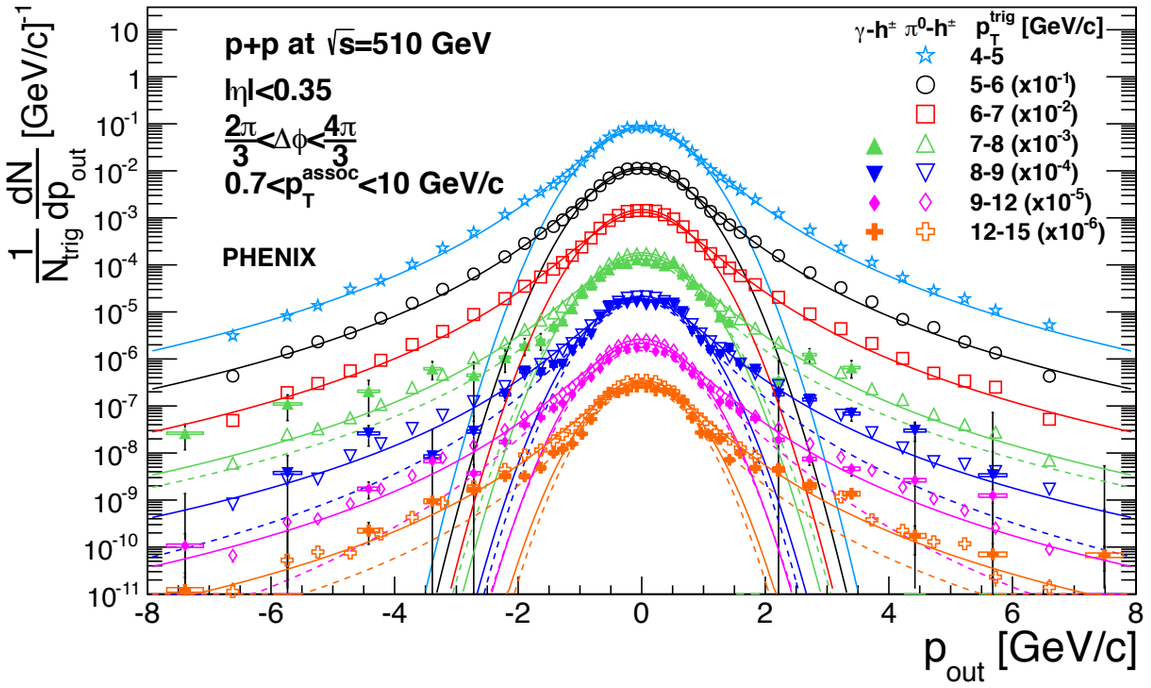
- Important check of understanding of perturbative QCD in a transverse momentum dependent framework - results from same physical mechanism leading to Sivers sign change

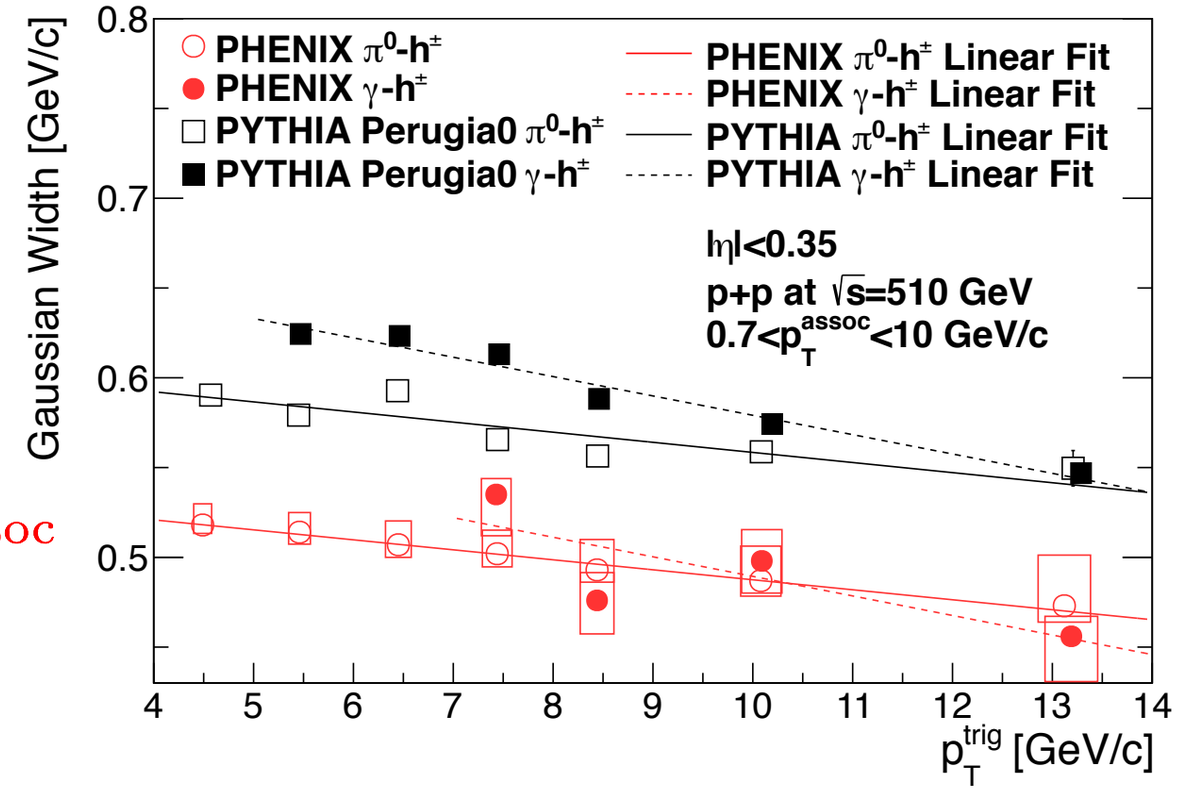


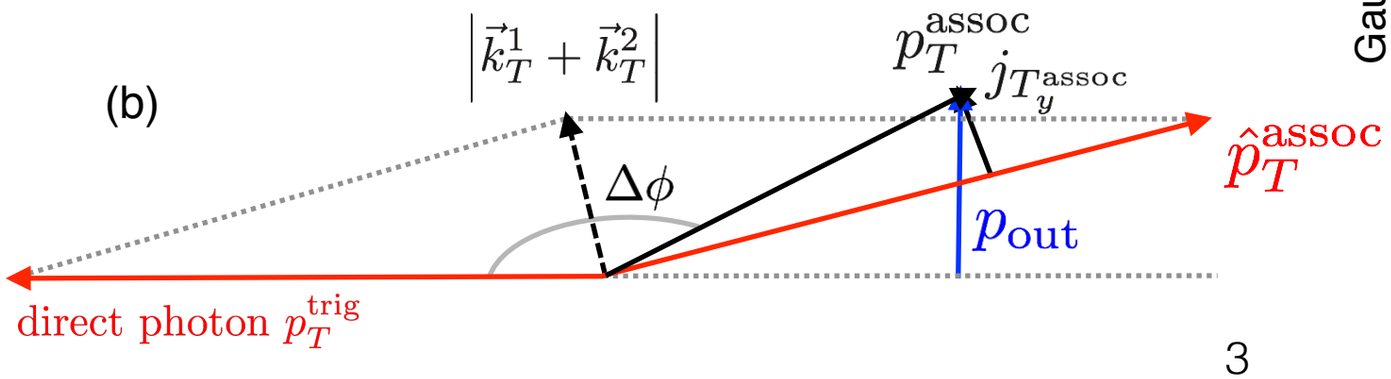
- Perturbative evolution predicts that momentum widths sensitive to nonperturbative transverse momentum should increase with increasing hard scale
- Confirmed in Drell-Yan and Semi-inclusive deep-inelastic-scattering

Physics Motivation

- PHENIX recently submitted arXiv:1609.04769, dihadron and direct photon-hadron correlations
- Measurements show opposite trend from perturbative evolution prediction
- Ideal measurement is photon-jet: can study factorization breaking with control over fragmentation
- Sensitivity to convolution of k_T and j_T for γ-h; sensitivity to *only* k_T in γ-jet
- What role does the fragmentation play (if any)?

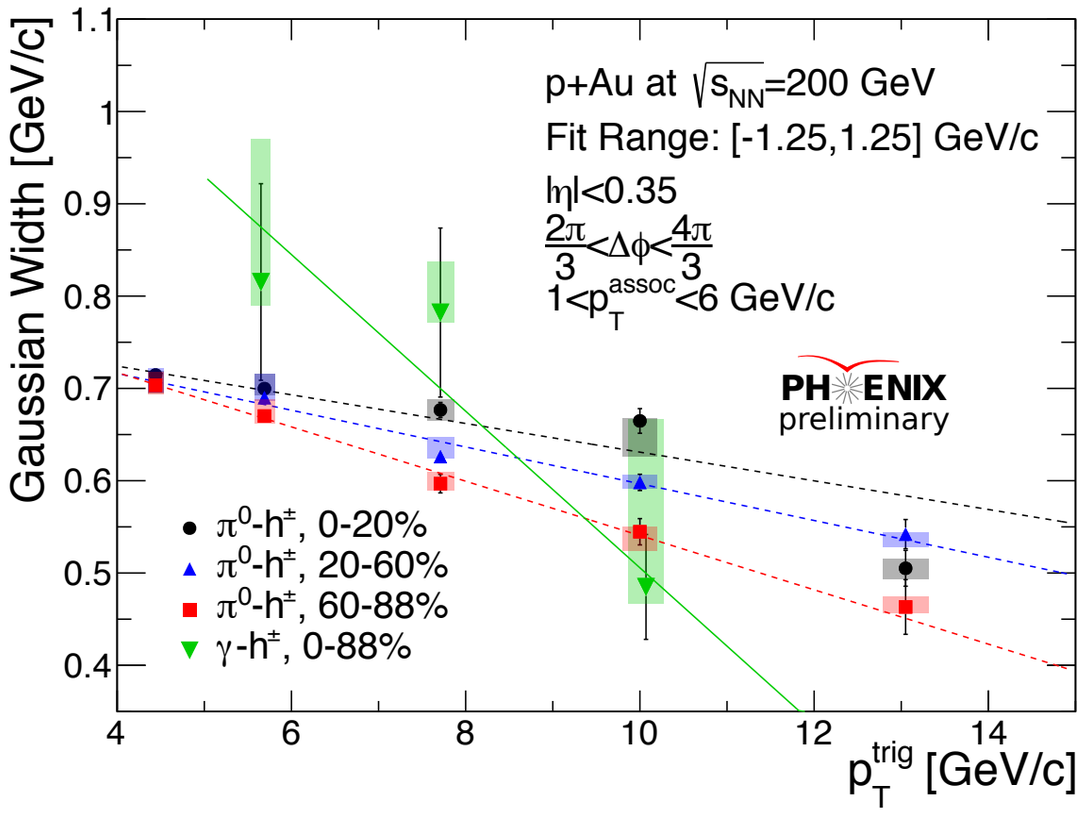






Physics Motivation

- New p+A results from PHENIX. Opportunity at sPHENIX to study cold nuclear matter effects also
- What role does a “classical” nucleus play?
- Stronger color fields?
- Can we disentangle effects from factorization breaking and multiple scattering/flow/Boer Mulders/etc.?
- What role does k_T broadening play?
- Many (many) questions that could be investigated



- Current γ-h$^\pm$ results suffer from low statistics
- sPHENIX will have significantly more integrated p+A luminosity
- Potentially can investigate spin dependence assuming statistics are large enough

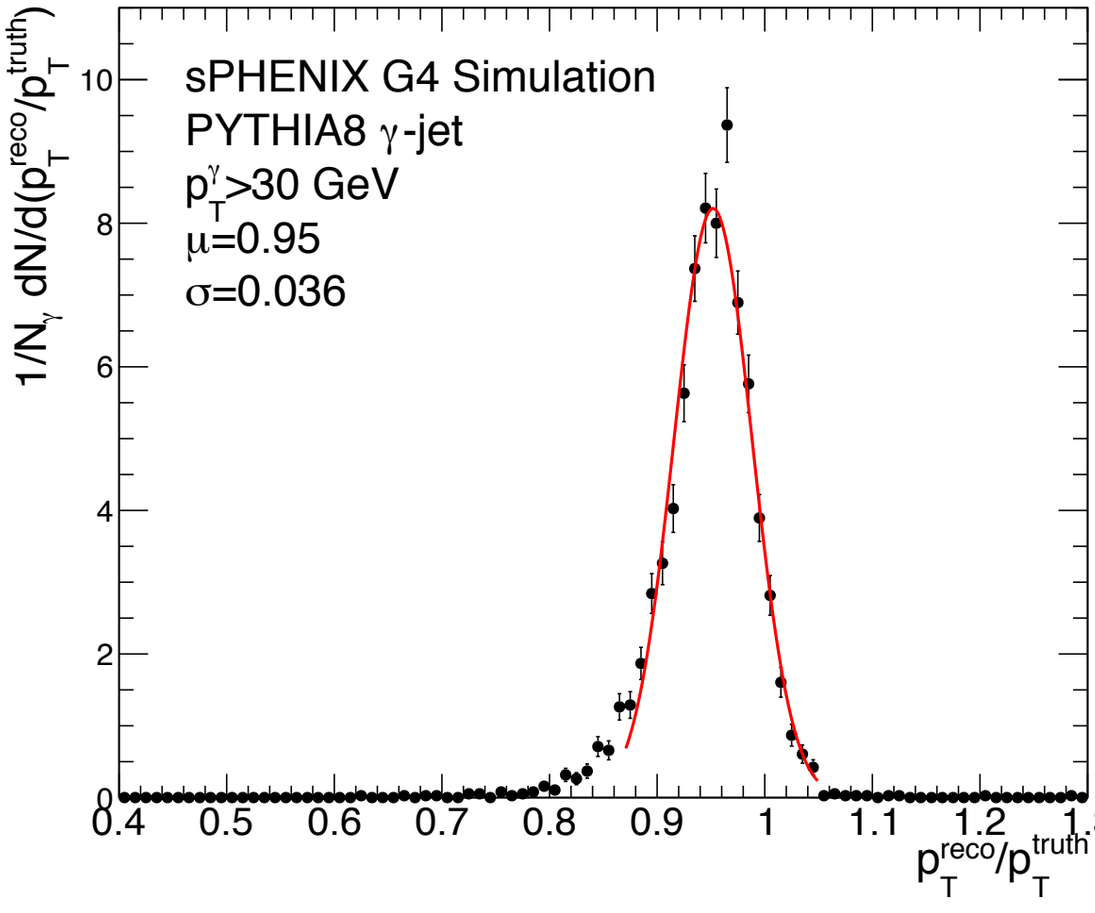
Method

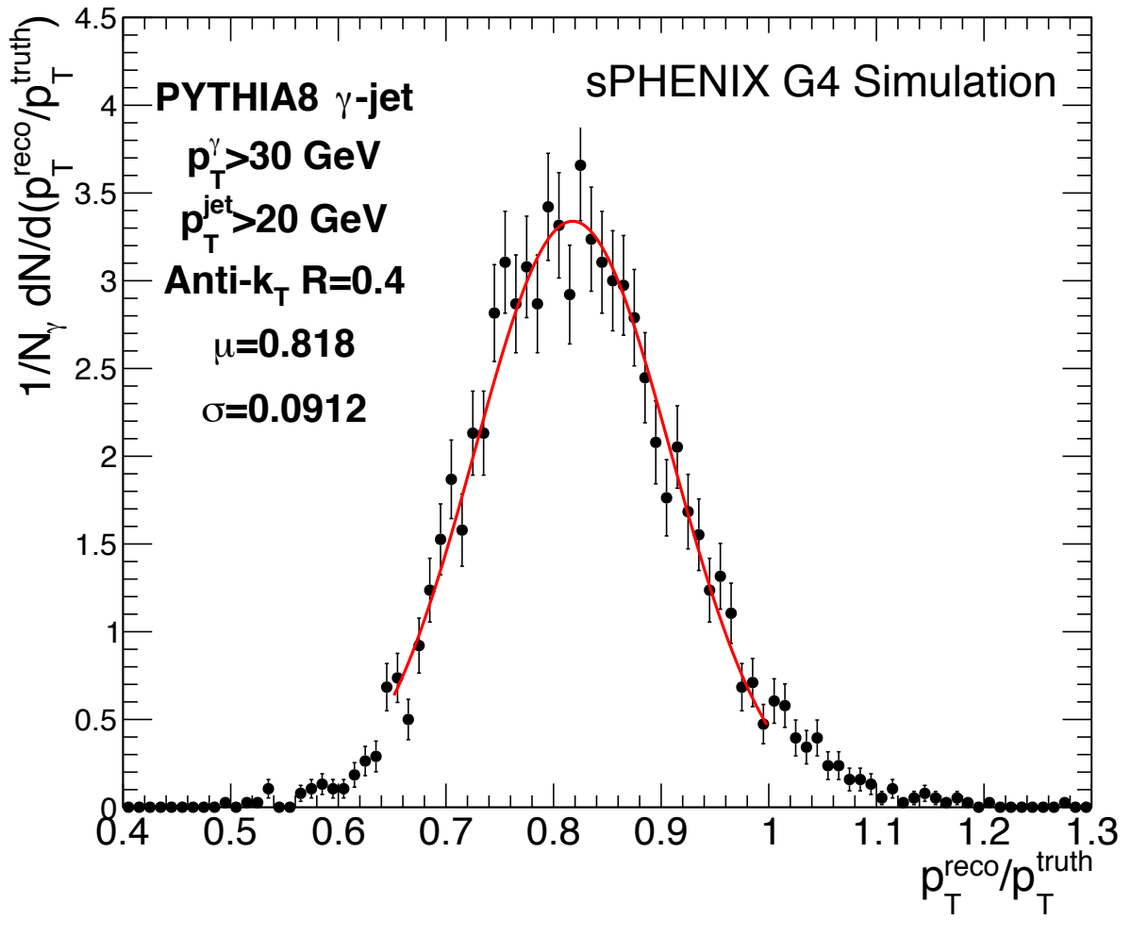
- Working with Jet Structure group as well - Currently have access to 10k PYTHIA8 direct photon-jet events with full GEANT simulation

- Collect (isolated) direct photons with away-side jets and hadrons

- Analysis code PhotonJet is in GitHub - Anyone can use and take a look at the already produced PYTHIA and G4 hits files by Dennis/Chris

Photon and Jet Response

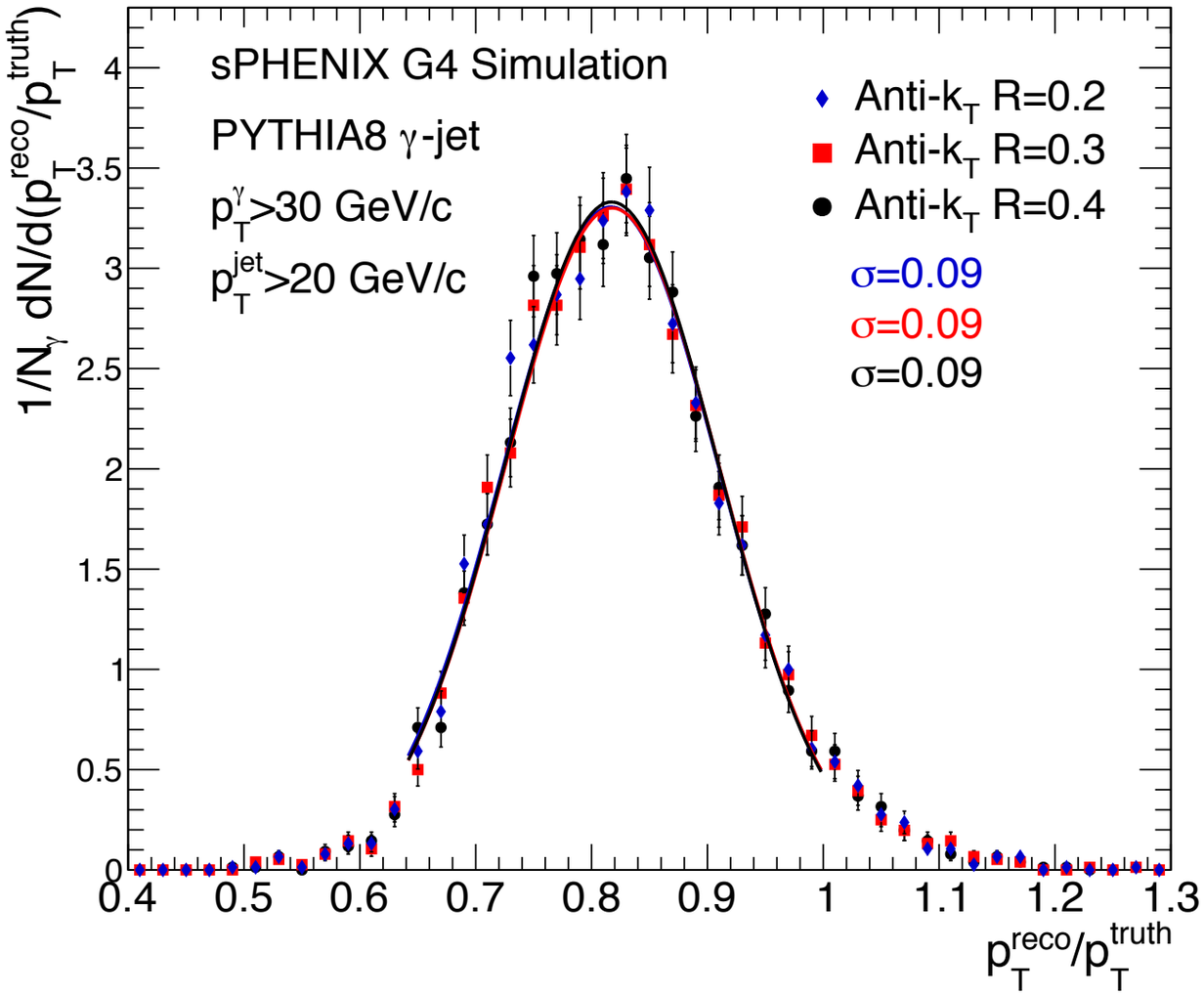




- Results match Dennis' shown at the sPHENIX collaboration meeting

Jet Response

- All small cone sizes have similar jet response
- Potential to study γ-jet as a function of jet cone size
- Future study: jet p_T resolution as a function of p_T and R



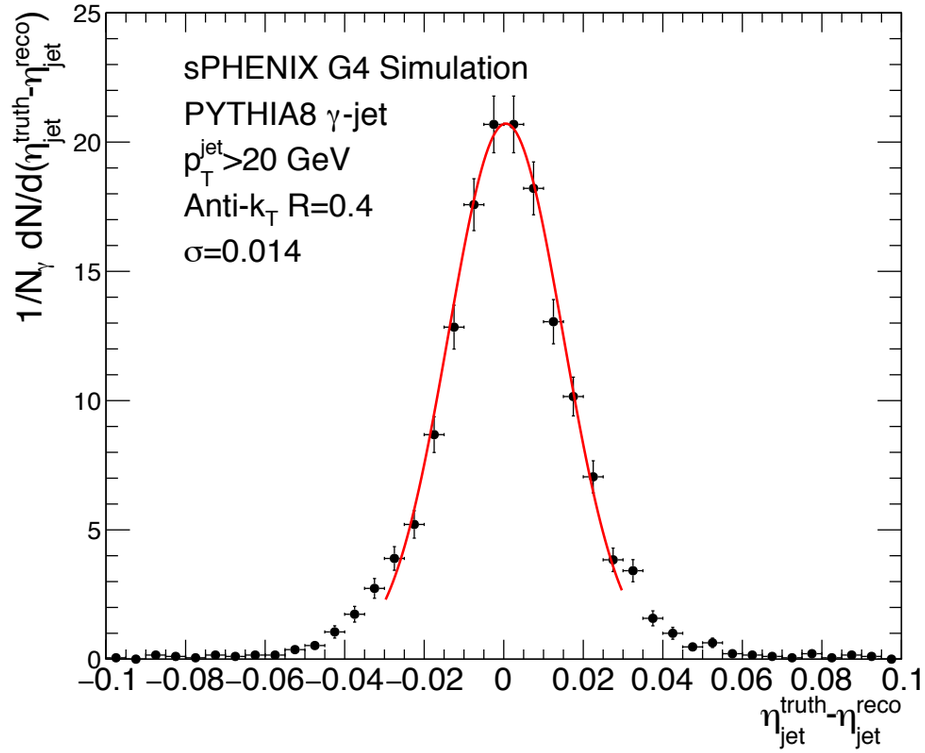
sPHENIX Jet Resolution

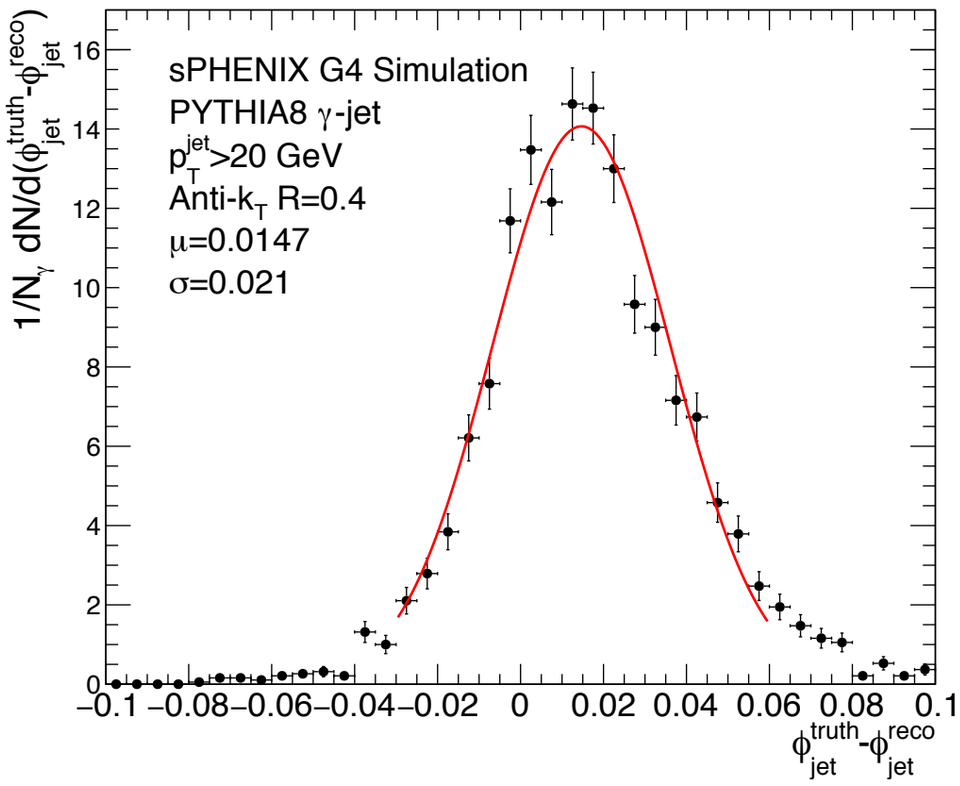
- To measure $p_{out}=p_T^{assoc}\sin(\Delta\phi)$, need good resolution of jet angles and p_T

- Good ϕ and η resolution: ~0.02

- ϕ offset due to HCAL detector geometry - working to investigate/recalibrate further

- Photon ϕ resolution is small compared to jet ϕ resolution

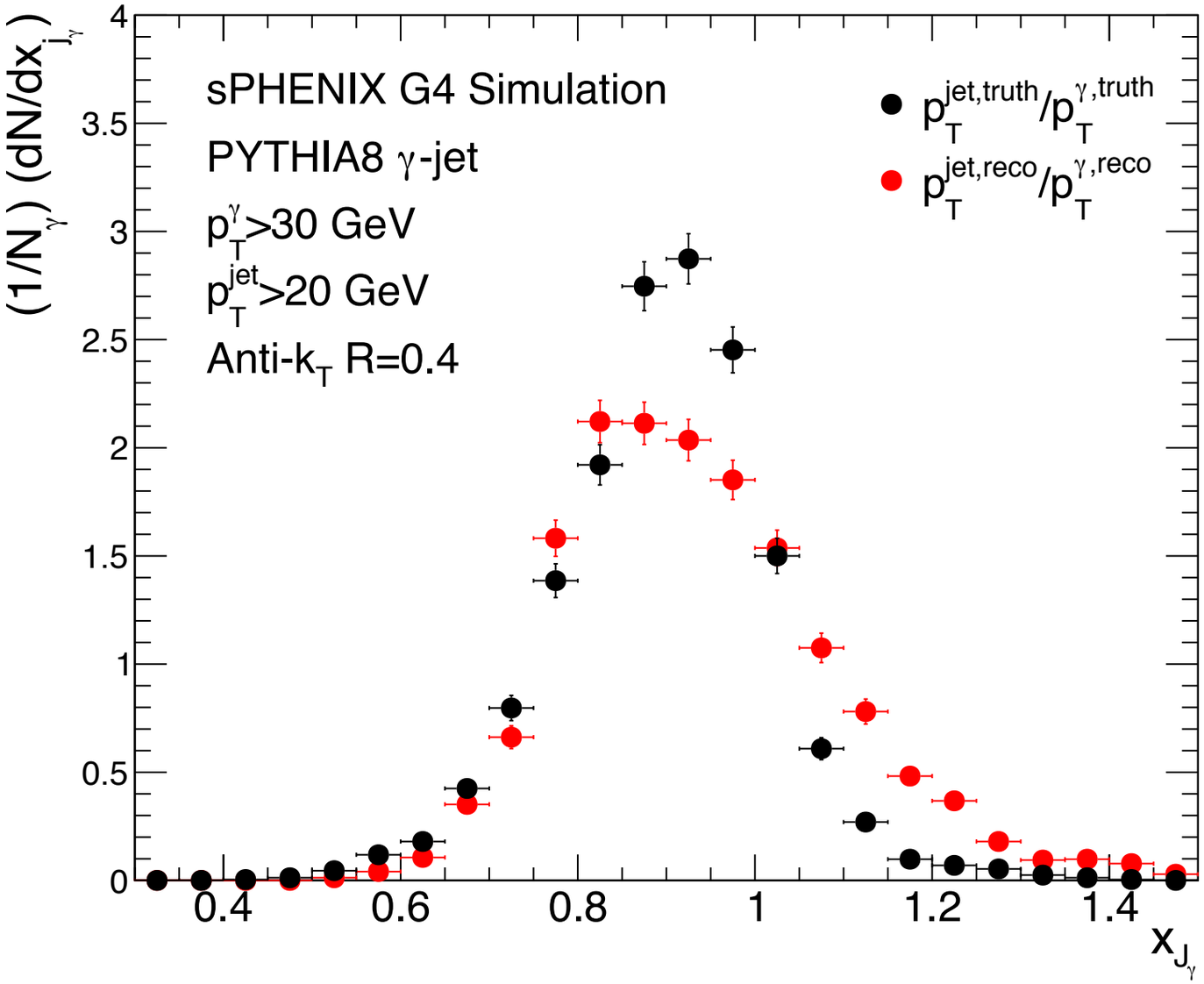




γ-Jet Observables

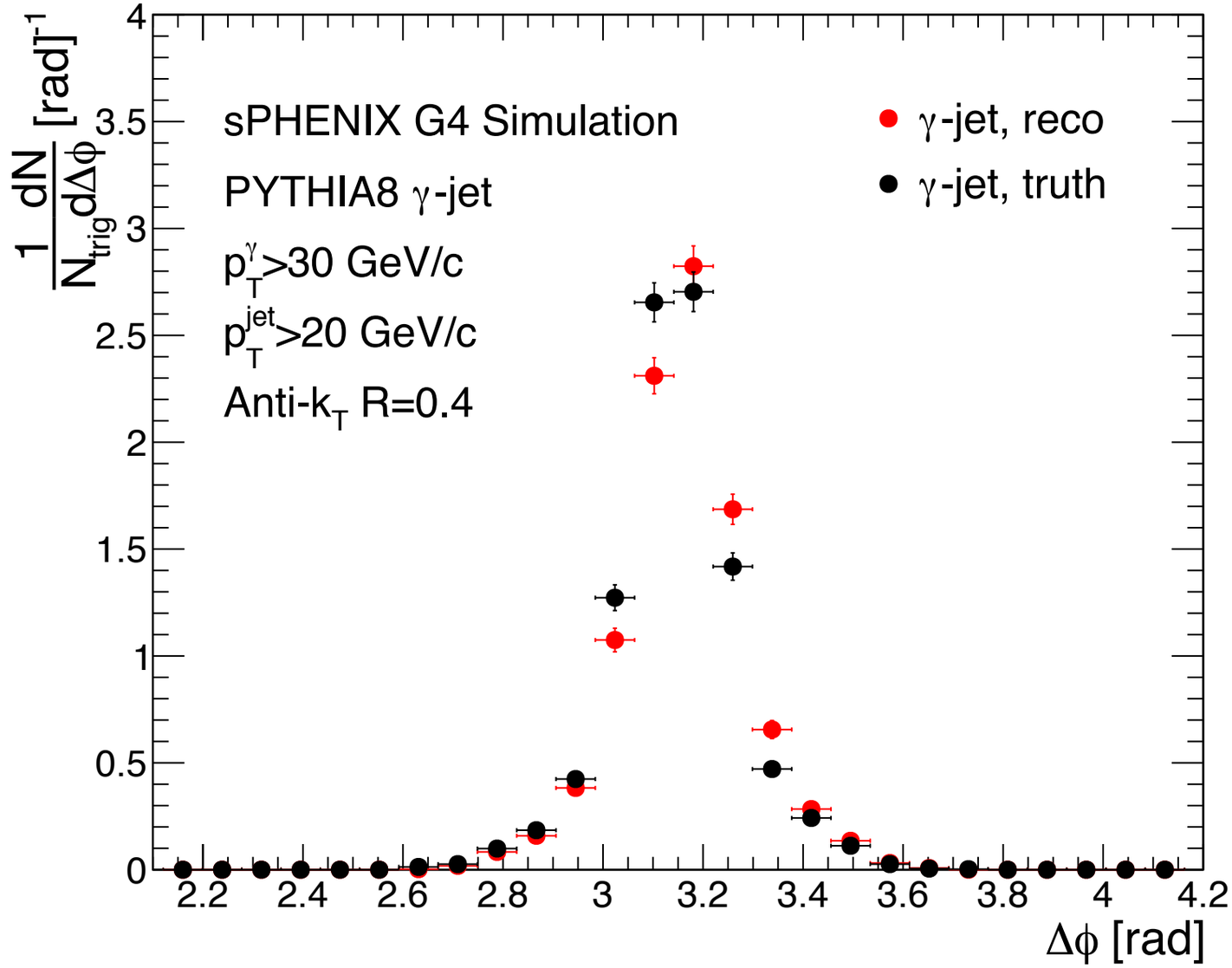
- p_T balance of γ-jet corrected for photon and jet response (1/0.82 and 1/0.95)

- p_T imbalance already shows presence of k_T acoplanarity at truth level



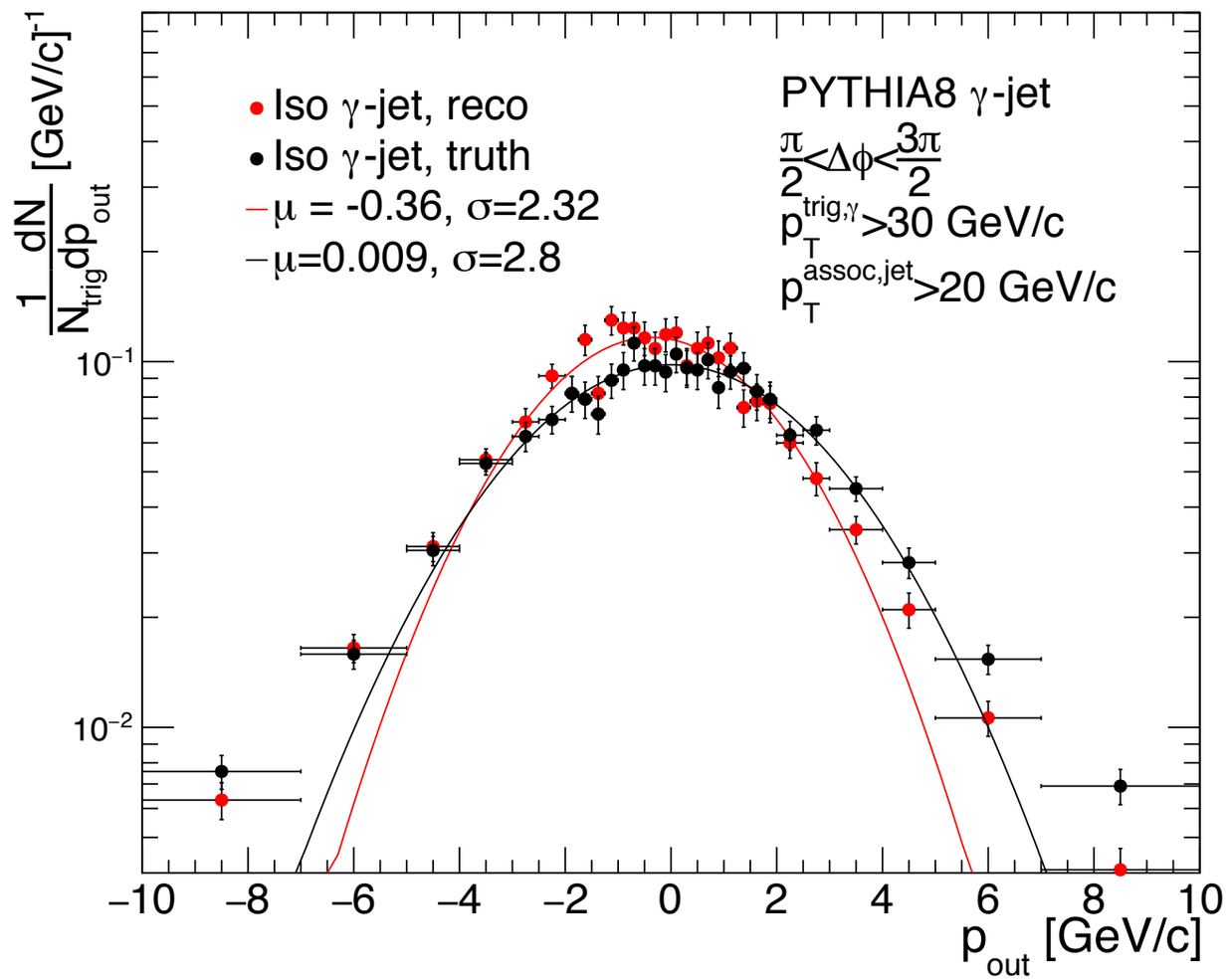
Δϕ Response

- Reconstructed distribution compares reasonably to truth distribution
- Asymmetry about π is due to jet ϕ resolution asymmetry



p_{out} Response

- p_{out} shows similar asymmetry about 0 due to jet ϕ resolution
- It appears that there should be sufficient statistics to distinguish between perturbative and nonperturbative contributions
- Question: Can we treat in a TMD framework? Widths are quite large: ~2.5 GeV/c
  - These PYTHIA events are also at very high Q^2: p_T^{γ} >30 GeV
  - Clearly a two scale problem but 2.5 GeV/c is not as much on the order of Λ_{QCD}



What will we *actually* measure at sPHENIX?

- According to PYTHIA: $\sigma^{qg\text{—>}q\gamma} \approx 3\text{x}10^{-6}$ mb = 3000 pb
    - For RHIC kinematics qg—>qγ process dominates, ~85% of direct photon events
- From the RHIC Cold QCD plan:
    - Expect 300 pb^{-1} pp at 200 GeV luminosity
- 3000 x 300 x 0.85 = 765,000 γ-jet events in pp seems way too large (because it is), doesn't include acceptance/efficiency/jet reconstruction etc….
- Plan to do a full PYTHIA+GEANT simulation to determine what our reconstruction efficiency will actually be as a function of p_T^{γ}
- This would in principle be useful to the collaboration as a whole as γ-jet is also of interest to e.g. Jet Structure topical group

Summary and To-Do

- Factorization breaking of nonperturbative functions predicted in p+p—>h+X
- Recent PHENIX paper studied p+p—>h+h+X, p+p—> γ+h+X. Ideal measurement is γ+jet due to control over fragmentation, amongst other things
- Currently analyzing Jet Structure Group's 10k γ-jet events with p_T^{γ}>30 GeV/c, preparing some jet reconstruction plots for QM17
- To Do
  - Would like to study a broader range of p_T^{γ}. will start working with my own PYTHIA files down to p_T^{γ}~10 GeV/c
  - Determine how small p_T^{jet} sPHENIX can measure to? That will ultimately be the limit for direct photon-jet measurement in p+p collisions
  - Working on a full PYTHIA+GEANT simulation study of acceptance and efficiency to determine how many γ-jets we will actually measure

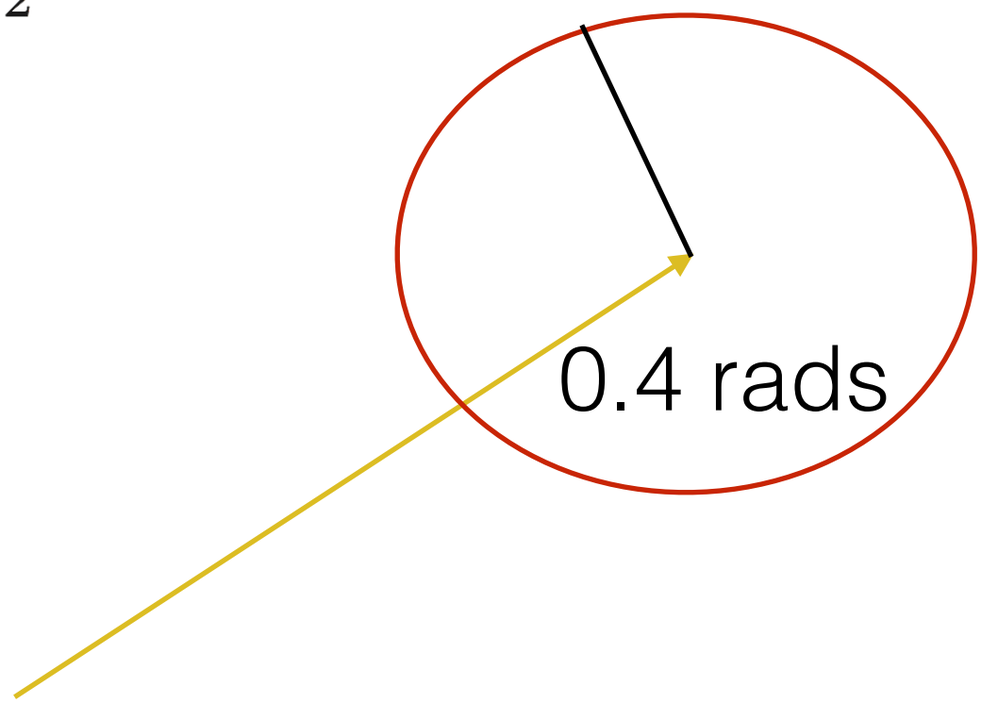
Back Up/Extras

Isolation Cut

- Studying effect of isolation cut on direct photon
- Current requirements:
- Isolation cone of $R = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$ 0.4 radians
- Entire isolation cone region restricted to be within |η|<1

$$\Sigma(E_\gamma + p_T^{tracks}) < 0.1 \times E_\gamma^{iso}$$

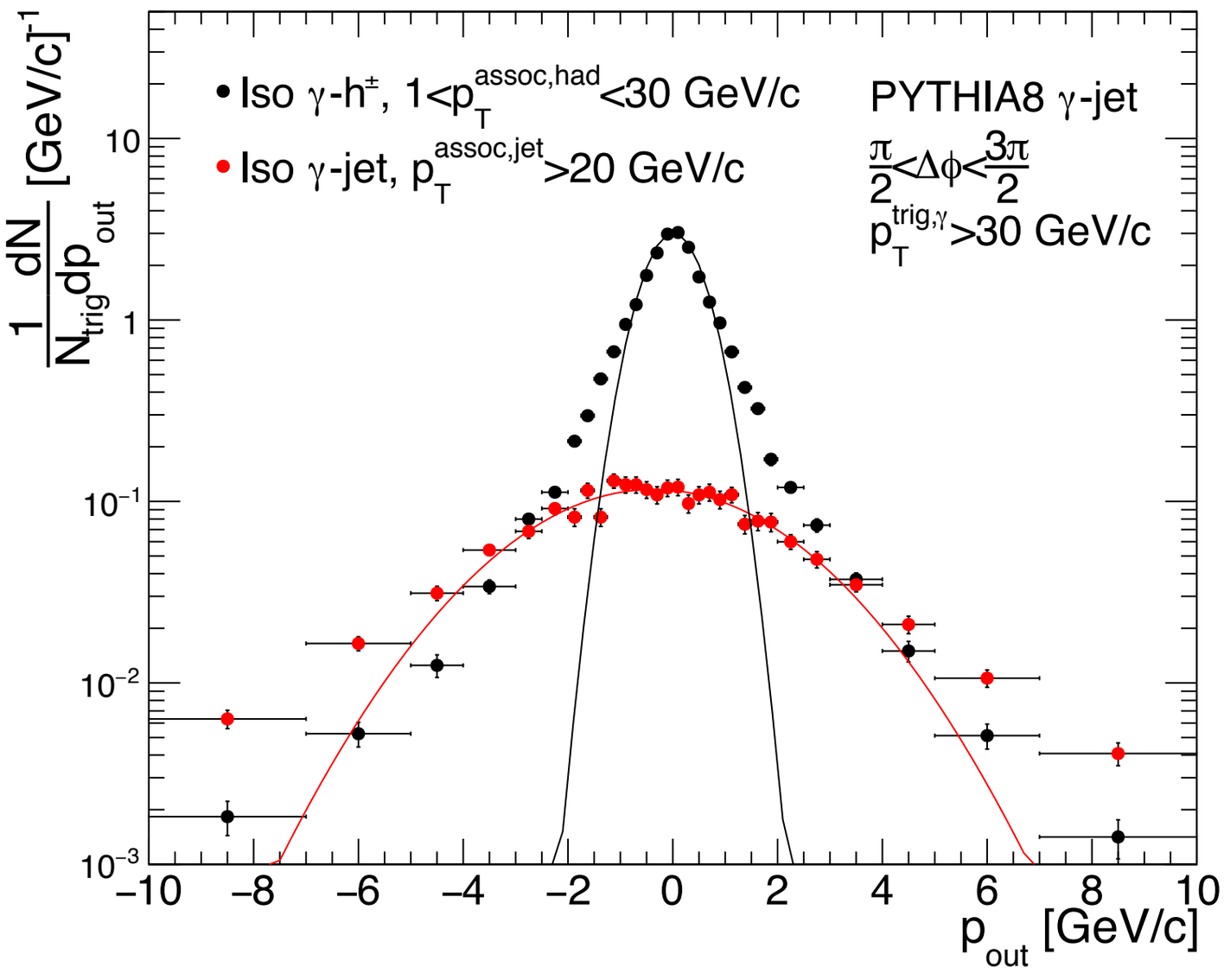
- Results in ~4000 of the 10000 photons
- This can obviously be altered depending on isolation cone size, energy restriction, etc.



γ-jet vs. γ-h

- γ-jet allows control over fragmentation

- Addition of second nonperturbative final-state scale j_T draws widths in significantly



Δϕ Resolution

- Δϕ resolution shows same behavior as jet ϕ resolution
- Same mean and width for the Gaussian
- Indicates resolution for Δϕ is dominated by the resolution on the jet azimuthal angle